

# Modulus vs Toughness

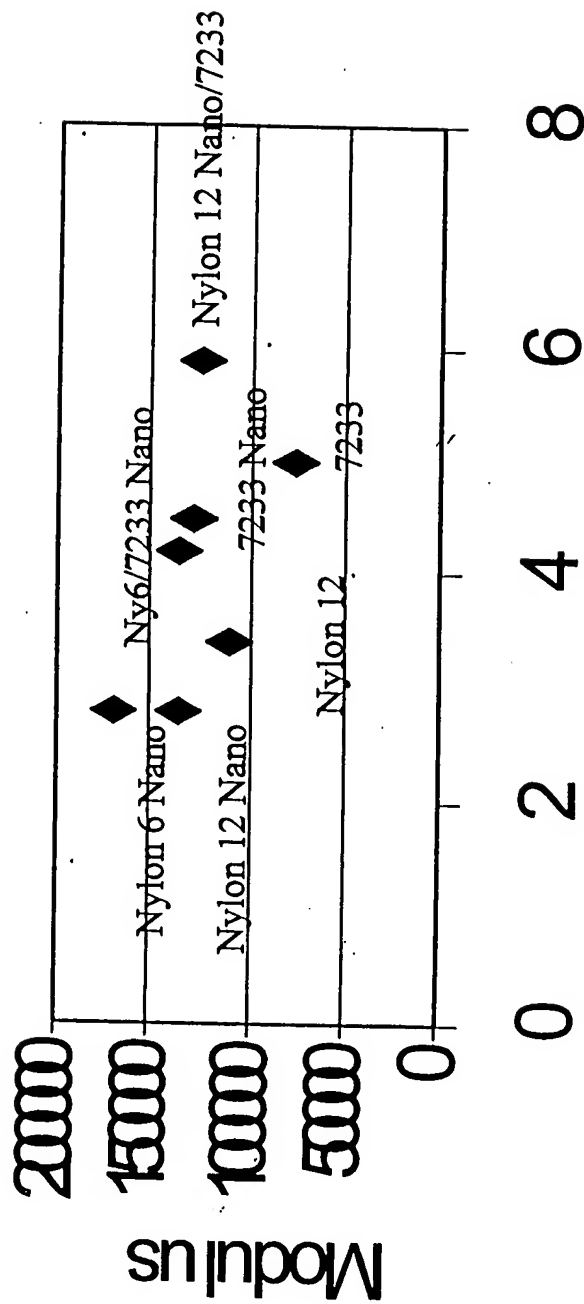


Figure 1

## Nylon Nanocomposite Versus Standard Nylon Tubing

		Effect of Nanoparticles	
Mechanical Properties	Durometer (Modulus)	++	
	Burst Pressure	+	
	Tensile Strength	+	
	Tensile Elongation	-	
	Tear Strength	+	
	Heat Resistance (HDT)	++	
	Dimensional Stability	++	
Surface Properties	Dirt Retention	+	
	Printability	+	
	Lubricity	+	
Barrier Properties	Gas Barrier	++	
	Solvent Resistance	+	
	Aroma Barrier	+	
	UV Barrier	+	
++ Much Improved		+ Slightly Improved	- Not Improved

Figure 2

# Nylon 12, Nylon 12 Nano, Pebax 7233, and Pebax 7233 Nano

Property	ASTM Test Method	Nylon 12 Aesno TL	Nylon 12 Nano 5% I42	Pebax 7233	Pebax 7233 Nano 5% I42
Tensile Modulus	D638 (psi) Young	260,000	312,000	134,000	208,000
Tensile Str. @ Break	D638 (psi)	6800	6800	4785	5400
Elongation @ Break	D638 (%)	256	329	458	464
Hardness Shore D	D2240	D74	D78	D70	D72
Melting Pt.	D3418 (deg C)	179	178	172	172
Specific Grav. (g/cc)	D792	1.02	1.04	1.02	1.03

\*Increase of Stiffness and Ductility on Injection Molded Tensile Bars

\*I42 is the nanoparticle from Nanocor fully designated I.42.TC

Figure 3

**Nylon 12, Nylon 12 Nano, Pebax 7233, and Pebax 7233 Nano 6F Catheter Tubing**

Property	ASTM Test Method	Nylon 12 Aesno TL	Nylon 12 Nano 5% I42	Pebax 7233	Pebax 7233 Nano 5% I42
Tensile Modulus	D638 (psi) Young	110,000	136,000	75,000	127,000
Tensile Str. @ Max. load	D638 (psi)	8600	5500	11,000	9000
Elongation @ Break	D638 (%)	396	500	456	502
Tens strength x Elong @ break	(x 1,000,000)	3.4	2.8	5.0	4.5
Melting Pt.	D3418 (deg C)	179	178	172	172
Specific Grav.	D792 (g/cc)	1.02	1.04	1.02	1.03
Dimensional Stability		-	++	-	++
Dirt Retention		-	+	-	+

**\*Increased Stiffness and Ductility Plus With Dimensional Stability and Improved Surface**  
**\* Control of modulus from 75,000 to 136,000 all at similar melting points**

**Figure 4**

**Nylon 11, Nylon 11 Nano, Pebax 2533, and Pebax 2533 Nano 6F Catheter Tubing**

Property	ASTM Test Method	Nylon 11 Resno TL	Nylon 11 Nano 5% I42	Pebax 2533	Pebax 2533 Nano 5% I42
Tensile Modulus	D638 (psi) Young	112,000	134,000	<5000	<5000
Tensile Str. @ Max. load	D638 (psi)	12,600	7400	-	-
Elongation @ Break	D638 (%)	462	462	>500	>500
Tens strength x Elong @ break	(x 1,000,000)	5.8	3.4	-	-
Melting Pt.	D3418 (deg C)	190	190	-	-
Specific Grav.	D792 (g/cc)	1.03	1.05	1.01	1.02
Dimensional Stability		-	++	-	+
Dirt Retention		-	++	-	+

**Figure 5**

**Nylon 12 Nano, Pebax 7233, Nylon 12 Nano/7233, and Pebax 7233 Nano 6F Catheter Tubing**

Property	ASTM Test Method	Nylon 12 Nano 5% I42	Pebax 7233	Nylon 12 Nano/ Pebax 7233	Pebax 7233 Nano 5% I42
Tensile Modulus	D638 (psi) Young	136,000	75,000	124,000	127,000
Tensile Str. @ Max. load	D638 (psi)	5600	11,000	12,000	9000
Elongation @ Break	D638 (%)	500	456	494	502
Tens strength x Elong @ break	(x1,000,000)	2.8	5.0	5.9	4.5
Melting Pt.	D3418 (deg C)	178	172	—	172
Specific Grav.	D792 (g/cc)	1.04	1.02	1.03	1.03
Dimensional Stability		++	—	++	++
Dirt Retention		++	—	++	++

\*Nylon 12 Nano/Pebax 7233 is a 50/50 blend with total nanoparticles concentration of 2.5%

Figure 6

**Nylon 12 Nano, Nylon 11 Nano, Nylon 12 Nano/7233, and Nylon 11 Nano/7233 6F Catheter Tubing**

Property	ASTM Test Method	Nylon 12 Nano 5% I42	Nylon 11 Nano 5% I42	Nylon 12 Nano/7233	Nylon 11 Nano/7233
Tensile Modulus	D638 (psi) Young	136,000	134,000	124,000	113,000
Tensile Str. @ Max. load	D638 (psi)	5600	7400	12,000	5100
Elongation @ Break	D638 (%)	500	462	494	251
Tens strength x Elong @ break	(x1,000,000)	2.8	3.4	5.9	1.3
Melting Pt.	D3418 (deg C)	178	190	—	—
Specific Grav.	D792 (g/cc)	1.04	1.05	1.03	1.04
Dimensional Stability		++	++	++	++
Dirt Retention		++	++	++	++

\*The 50/50 blend of Nylon 12 Nano/Pebax 7233 was superior to the corresponding 50/50 blend of Nylon 11 Nano/Pebax 7233

Figure 7

**Nylon 12 Nano, Nylon 6 Nano/7233, and Nylon 6 Nano/2533 - 6F Catheter Tubing**

Property	ASTM Test Method	Nylon 12	Nylon 6	Nylon 6 Nano/Nylon 6 Nano/7233	Nylon 6 Nano/2533	*Nylon 6 Nano/7233 Nano
Tensile Modulus	D638 (psi) Young	136,000	171,000	136,000	94,000	356,000
Tensile Str. @ Max. load	D638 (psi)	5600	9900	10,000	10,000	13,000
Elongation @ Break	D638 (%)	500	287	415	600	338
Tens strength x Elong @ break	(x1,000,000)	2.8	2.8	4.2	6.0	4.4
Melting Pt.	D3418 (deg C)	178	217, 274	-	-	-
Specific Grav.	D792 (g/cc)	1.04	1.12	1.06	1.06	1.07
Dimensional Stability		++	-	-	-	-

Dirt Retention ++  
 Nylon 6 Nano XA2908 was obtained from Honeywell International at a reported nanoparticle level of 2.0%. The addition of Pebax to XA2908 improved processability and ductility.  
 \*for tubing 0.022" to 0.017"

Figure 8